MATING BEHAVIOR OF *PLATYNEUROMUS* (MEGALOPTERA: CORYDALIDAE), WITH LIFE HISTORY NOTES ON DOBSONFLIES FROM MEXICO AND COSTA RICA[1]

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ABSTRACT: This paper provides observations on mating behavior, oviposition, pupation, and adult life span of *Platyneuromus* from northeastern Mexico, as well as on larval habitats of *Chloronia*, *Corydalus*, and *Platyneuromus* recorded in Mexico and Costa Rica. *Platyneuromus*' mating behavior differed from that of *Corydalus* in that males only displayed threatening positions but did not fight. Further, they did not rest their mandibles over female's body after mating but softly bit and touched female's wings and abdomen with their mandibles. *Platyneuromus* larvae in northeastern Mexico appear to prefer higher elevation streams and a narrower spectrum of ecological conditions than *Corydalus*. Currently stable New World dobsonfly taxonomy should facilitate research on the largely unstudied life history traits of Neotropical taxa.

Three genera of dobsonflies (Corydalidae: Corydalinae) occur in the New World: *Chloronia*, *Corydalus*, and *Platyneuromus*. Relatively recent taxonomic revisions (Penny and Flint 1982, Glorioso and Flint 1984, Contreras-Ramos 1995, 1998) now facilitate studies on subjects such as description of immature stages, larval habitat and habits, voltinism, secondary production, mating behavior, and more.

Adult morphological variation, distribution, time of emergence, and co-occurrence of *Platyneuromus* species were treated by Glorioso and Flint (1984). However, this paper presents the first observations of eggs, larval habitat, mating behavior, and adult life span of any species in the genus. General information on larval habitat and coexistence of dobsonfly species in other localities of Mexico and Costa Rica are included as well. Most observations were recorded during a taxonomic study on the immature stages of *Platyneuromus* in northeastern Mexico (Nuevo León), during the summers of 1988 and 1989. Descriptions of the immature stages and detailed locality records are being published elsewhere (Contreras-Ramos and Harris 1998).

MATERIALS AND METHODS

Study Sites. Life history observations of *Platyneuromus soror* (Hagen) were recorded during a taxonomic project (Contreras-Ramos and Harris 1998) in the area of Santiago (south from Monterrey), Nuevo León, northeastern Mexico. Field work was done especially at a site known as Potrero Redondo (25.258° N, 100.160° W, elevation approximately 1400 m a.s.l.), within an oak-pine forest

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in the Sierra Madre Oriental (Figs. 1, 2). Several adults were reared in Monterrey (from prepupae collected at Potrero Redondo) and additional observations of mating behavior were obtained from these specimens. Localities in Mexico and Costa Rica, where larval habitat of *Corydalus* and *Chloronia* were recorded, are mentioned below.

Rearing and Observations of Mating Behavior. Seven pitfall traps were set up on the stream banks (cf. Azam and Anderson 1969) for collection of *Platyneuromus* larvae leaving the water to pupate. No larvae were captured by the traps in a 5 day period (June 23–28, 1988). Nonetheless, prepupae and pupae were collected from chambers under stones and rocks along the stream margins. No attempt was made to rear *Platyneuromus* larvae, but several adults were obtained from prepupae and pupae. Plastic containers (250 cc) with perforated caps were filled with soil from the stream banks. Prepupae were placed in a furrow made in the soil within the containers and covered with a flat stone. Soon new chambers were built by the prepupae. Containers were inspected daily to record time of pupation and emergence. Mature larvae occasionally can be induced to pupate by transferring them to a soil container. I have successfully reared adult *Nigronia* and *Corydalus* in this fashion. However, some larvae do not pupate and eventually die after a few weeks. Adults of both sexes of *Platyneuromus*, either collected with blacklight or reared, were allowed to

Fig. 1. Location of some study sites where life history observations were recorded.

Figs. 2–5. Some study sites where life history observations were recorded: 2 — Potrero Redondo (Santiago, Nuevo León); 3 — Las Adjuntas (Santiago, Nuevo León); 4 — La Poza Azul (Gómez Farías, Tamaulipas); 5 — Río Máquinas (Los Tuxtlas, Veracruz).

mate. In the field, adults were placed in a terrarium measuring approximately 76 x 30 x 30 cm. For simulating natural conditions, the terrarium bottom was covered with moss and liverworts and a couple of twigs were placed from bottom to sides. The terrarium top was covered with a finely meshed screen. Red light was used for illumination (Evans 1972), because other colors are disturbing to these insects (e.g., white and blue). Recorded times of activity are in local time. After mating and egg masses being laid, a small container with stream water was placed under them for capturing first instars upon hatching. One mature egg mass was preserved in 80% ethanol.

Biological and Ecological Observations. Throughout the study, observations on habitat, co-occurrence of megalopteran genera, and duration of life stages were recorded. Hellgrammites were collected from streams by disturbing substrates such as vegetation, rocks, and leaf packs, or from under bark of submerged logs. Standard aquatic nets, enamel pans, and forceps were used for capturing and sorting the larvae. Acid alcohol (9 parts 80% ethanol, 1 part glacial acetic acid; modified from Stehr 1987) served as the killing agent. Within a few hours from collection, larvae (length $\geq$ 20 mm), as well as prepupae and pupae were injected orally with the same acid alcohol solution in which they were kept. After approximately 24 hours specimens were transferred to 80% ethanol for final storage. Surgical gloves were used for handling specimens fixed with acid alcohol.

RESULTS AND DISCUSSION

Mating Behavior. Two females and two males collected with blacklight on June 24, 1988, were placed in a terrarium to observe their courtship and mating. Adults became active at dusk. Mating attempts were observed but copulation was not accomplished during the observation period. At about 2145 hours the following day (June 25), copulation occurred. Courtship began when the male held his wings straight and flat with the abdomen tip directed upright and the tenth tergites standing over the level of the wings ("arrogant" display posture). The male also fluttered his wings at short intervals (with no abdominal vibration). Following this display the female bent her abdomen forward by her left side, as the male did but in the opposite direction. Copulation was performed on the moss and liverworts (terrarium floor) and lasted about 30 seconds. At 0400 hours on June 26, the adults became inactive and two egg masses had been laid (cf. "eggs" below). Later, the first pair of males were replaced and two females were added. The adults became active around 1945 hours (June 26), just prior to sunset. At 2037 hours one copulation took place, after which the female proceeded immediately to drink water from the liverworts. The male briefly rubbed the female's wings with his mandibles (about 2 minutes), and her antennae with his antennae, perhaps as a mate guarding behavior. Then, he moved away. No additional direct contact was observed. Occasionally and apparently unconnected with mating, females were observed to flutter their wings

without flying, moving the abdomen up and down quickly. Eventually, they would fly and hit the terrarium walls.

Mating behavior of adults reared from prepupae was also observed on July 3 and 5 in Monterrey (see "eggs" below). The first day, one of three males attempted to mate with the only female for a period of about 10 minutes. He followed the female continually, walking ventral side up on the screen covering the terrarium, attempting copulation constantly. At times, the female stopped and the male touched her abdomen (tip and middle) with his mandibles and antennae, also softly biting her wings. The male attempted copulation by bending his abdomen forward at either side, trying to grasp the female's abdomen with his tenth tergites. Every time the male's tenth tergites slid toward the tip of the female abdomen, contact was lost, so copulation did not occur. Wing fluttering behavior of the male was not observed during this pairing. On the second day, at about 0120 hours, one male displayed the wing fluttering behavior while walking on the screen covering the terrarium followed by several attempts to mate with the only female. A few minutes later, two males faced each other climbing a twig. They remained for a few seconds with their mandibles open in threatening position, but they did not fight.

During the observations a strong smell prevailed in the room. This smell, rather foul, was also evident in the alcohol in which males were preserved. This phenomenon has been reported previously for males of *Corydalus* and *Orohermes* (Evans 1972). Possibly, the membranous foldings behind the ninth sternum of males might be glandular and serve as scent glands. Internal, posterolateral pregenital sacs (on the eighth abdominal segment) in *Platyneuromus* and some *Corydalus* may have a similar function. Female *Chloronia*, *Platyneuromus*, and several phylogenetically basal *Corydalus* have an abdominal pouch posteroventrally on the 6th segment. The pouch's function is unknown. It appears to be eversible, as observed in some alcohol preserved specimens, and it might also be glandular. However, oberved female dobsonflies did not have a strong smell associated with them.

From these observations, it seems that the more active role during mating is performed by the male, who pursues the female while attempting copulation. A striking feature I observed, which suggests a discrete precopulatory courtship, was the male's behavior of keeping the wings straight, fluttering them intermittently, and holding the terminalia upright above the level of the wings (Fig. 6). A similar pattern was reported by Evans (1972: 80) for *Corydalus texanus* (as *C. cognatus*): "...the male became active, fluttering his wings and walking about with his abdomen held off the substrate..." However, Evans' description does not clearly indicate if the male's terminalia were held above the level of the wings. The precopulatory behavior mentioned by Evans (1972: 80) for *C. cornutus* and *C. texanus* consists "...of [1] touching their antennae in a head-to-head position, followed by [2] the male sometimes placing his head across the female's wings..." Parfin (1952: 430) described the second pattern in *Corydalus*

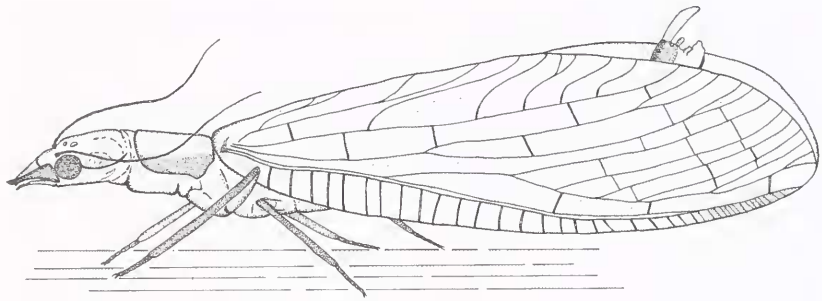

Fig. 6. Male *Platyneuromus soror* in pursuing behavior with genitalia upright.

cornutus: "...the male...placed his mandibles over the wings of the female and the two remained in that position during the next hour..." I observed the first behavior (head-to-head position) one time in *Platyneuromus*, but the males never rested their head on the female's wings. Such possibly mate-guarding behavior, presumably serving to assure paternal investment (Henry 1997), was not strictly observed in *Platyneuromus*, but I did observe a male that stayed with the female for a brief period after mating (about 2 minutes). Both Evans and Parfin observed mating of *Corydalus* to occur only on vertical surfaces. By comparison, I observed males of *Platyneuromus* attempt copulation on the bottom of the terrarium, ventral side up on the screen covering the terrarium, and on the twigs set diagonally inside the terrarium. Although large, gelatinous spermatophores have been reported to be attached externally to the female dobsonfly genitalia (Hayashi 1992, 1993), I did not observe this phenomenon here. Such behavior, probably overlooked, is most likely part of mating in *Platyneuromus*.

Mating behavior of Neotropical dobsonflies is poorly known. I suggest that detailed comparative studies of mating behavior should help unravel patterns across species and genera. In turn, such patterns may prove to be useful sources of characters for phylogenetic hypotheses.

Eggs. At Potrero Redondo, *P. soror* adults were collected with blacklight on June 24, 1988, and allowed to mate in a terrarium. The mean ambient temperature range was 18.3–23.3°C. Two days later, at approximately 0100 hours, two egg masses were laid. One of the egg masses was glued to the glass wall of the terrarium, the other to the sealant between the walls. The egg mass on the glass measured approximately 12 x 13 mm. Both egg masses were round, slightly convex, chalky white, and similar to those of *Corydalus* as described by Baker and Neunzig (1968), and to several others observed from Alabama and Mexico. The terrarium was then transported to Monterrey, Nuevo León, where the remaining development period took place, at a mean temperature range of 30.3–

32.7°C (high with respect to natural habitat conditions). Both egg masses hatched 16 days after being laid. A third, irregular (elongate) egg mass was laid on July 3, 1988, and was preserved after 9 days. The larvae, inside the eggs, were almost completely developed.

The only eggs of *Platyneuromus* available to me for study were almost fully developed, and therefore, no attempt is made here to give a formal description. However, under dissecting microscope, the chorion appeared smooth and translucent; also, the egg shape was elongate, subcylindrical, with a micropylar process. Eggs were glued to each other by a cementing matrix. Egg shape and micropylar process were similar to those of *Corydalus* illustrated by Baker and Neunzig (1968).

Pupation. At Potrero Redondo, seven pitfall traps were placed along the stream banks on June 23, 1988. The traps were inspected daily for five days, but no prepupae were captured. However, during the same period 21 prepupae and six pupae were collected from under stones, approximately 15 larvae were collected from the stream (all immature), and nine adults were captured with a blacklight trap. Based on these collections, peak emergence appears be around the dates of collection and larval migration from the stream had already occurred. My observations agree with Glorioso and Flint (1984), who reported that the peak of abundance for *P. soror* seemed to fall between May and early July throughout its distributional range.

I found prepupae and pupae as far as 20 m from the stream with specimens being collected from the stream bank and onto a forested hillside. However, most of them were found close to the stream. Pupation sites far from the water also have been indicated for *Corydalus* (Howard 1908, Parfin 1952). I found both life stages under rocks or stones, ranging in size from 20–45 cm long. Pupation substrates varied from dry to very humid and from gravel or sand to compact silt.

Eight prepupae, all collected on June 23, were allowed to pupate in containers with soil. Time spent as prepupae ranged from one to three days in four specimens and five to seven days in three specimens. The prepupae first were maintained at field temperature for three days (cf. "eggs" above), but they were held at city temperature (cf. "eggs" above) for the remaining days. Time spent as pupae was eight days for six specimens and 7 days for one specimen. Four of the pupae requiring eight days spent one or two days at field temperature, and the remaining three pupae spent the entire pupation period at city temperature. Time as prepupa and pupa was not recorded for one specimen. Two more specimens had a pupation period of nine days, with the first three days at field temperature. Based on five observations I made in the field, it appears that adult emergence occurs early in the morning while still dark, as early as between midnight and 0200 hours. These observations indicate that the prepupal period is at least seven days, and that pupation lasts at least another eight to nine days. Because temperatures in the city were considerably higher, it is likely that both

periods are longer under natural conditions. Studies under constant natural conditions are still necessary to determine actual duration of prepupal and pupal periods.

Adult Life Span. Of the nine adults collected with black light (cf. "eggs" above) and kept in captivity, one died after three days, four after four days, three after five days, and one after six days; the first three days under field temperature. One adult that emerged in the city lived four days. Three adults collected on August 6, 1989, lived for one week kept under air-conditioned temperature. Parfin (1952) reported an average longevity of eight days for both sexes of *Corydalus cornutus* in captivity. The actual life span of adult *Platyneuromus* in nature may be longer, with a shorter observed period caused by high temperatures and confinement conditions as inferred from damage on their wings and antennae.

While kept in the terrarium, adults of *Platyneuromus* were observed to drink readily from the water spread over the moss and liverworts. They drank also from small containers filled with a commercial sweet solution. Adults of *Corydalus* also have been reported to drink water (Parfin 1952).

Habitat. According to observations during adult collections of *Platyneuromus soror* in several parts of Mexico, it appears this species prefers clean, cool, well oxygenated permanent streams. Information gathered from museum specimens also suggests occurrence of this species, generally, at fairly high elevations (e.g., 610–2200 m, Glorioso and Flint 1984). *Corydalus*, on the other hand, seems to have a wider range of habitat conditions including warm, intermittent streams in arid zones, and habitats similar to those described above for *Platyneuromus*. Larvae of *Platyneuromus* were found mostly under rocks and stones in moderate to fast flowing riffles, but also in slow flowing water and on moss subjected to very fast current below falls. Hellgrammites were commonly captured with *Anacroneuria* (Plecoptera), *Leptonema* (Trichoptera), and several mayfly nymphs, among other groups.

Although larvae, pupae, and adults of only *Platyneuromus* have been collected at Potrero Redondo (altitude ca. 1400 m), both *Corydalus* and *Platyneuromus* co-occur in a nearby, also forested site (Las Adjuntas, Fig. 3) at a lower altitude (750 m). Further below, in the same general area (at about 500 m altitude), only *Corydalus luteus* has been collected, in streams with semiarid conditions. On May 13, 1989, I collected 23 larvae of *Platyneuromus* and five larvae of *Corydalus* from a stream at Las Adjuntas. These collections suggest a possible segregation of habitat based on altitudinal zonation. However, more evidence is required to document any ecological preferences (e.g., feeding habits), in sympatry and in allopatry, of species of both genera. Habitat selectivity has been documented for other dobsonfly species. For instance, *Chloronia hieroglyphica* is never found near large streams and rivers in northern Brazil (Penny and Flint 1982), and in Suriname, *Corydalus affinis* and *C. nubilus* appear to be confined to large open rivers, whereas *C. batesii* and *Chloronia hyeroglyphica* are confined to shadowed small bush creeks (Geijskes 1984).

***Corydalus luteus* Hagen.** On June 10, 1988, 26 larvae were collected from Arroyo Dolores, a small stream besides El Cercado, Municipio de Santiago, Nuevo León, Mexico (25.258° N, 100.142° W, elevation 475 m a.s.l.). The riparian trees were mainly *Taxodium mucronatum*, surrounded by shrubby vegetation within a semiarid environment. The stream was under drought conditions and was completely dry in some portions. Stream width was approximately 0.5 m where water was flowing, and only a few centimeters, or less deep. Numerous (tens) mature and immature larvae were found under rocks in humid soil on the stream bed; others were found in the short portions of the stream where water was flowing. In both cases, larvae were under crowded conditions.

For 10 days nine mature larvae were kept in an aquarium and fed raw hamburger. A pan with soil was placed on top of large stones so larvae could leave the water and crawl into the soil for pupation, as described by Smith (1970). Several larvae crawled into the pan with soil, but always returned to the water within minutes. The larvae were then transferred into bowls with soil, placed in furrows made with a finger, and covered with a flat stone. Only three larvae pupated taking 13–22 days for pupation to begin as evidenced by the excavation of pupal chambers. Pupation lasted for one week and the adults lived only two to four days at a mean temperature range of 32.6–33.1°C. Such high temperatures may have accounted for the rather short period of pupation, the very brief life of the adults, and for the minimal mating attempts that were observed. Two larvae that did not pupate died after 10 days of having been placed in soil. However, hellgrammites are capable of living out of the water (or in the water, without food) for long periods of time. One larva collected from Schultz Creek, Alabama, was kept alive in soil for over two months, eventually dying without pupating.

In northeastern Mexico, *C. luteus* larvae were collected from different microhabitats, such as fast flowing riffles in shallow streams, moss under fast current below falls, cobbles in fast flowing rivers (about 1 m deep), as well as under bark in slow flowing and deeper rivers (about 1 m deep or more). Also, *Corydalus* larvae seem to do well under both moderately polluted and disturbed habitats.

***Chloronia* spp.** On August 6, 1988, one male and seven females of *Chloronia mexicana* Stitz were collected with blacklight at the headwaters of the Río Frío (near "La Playita"), Ejido San Pablo, Municipio de Gómez Farías, Tamaulipas, Mexico. The following day, further downstream at a nearby site ("La Poza Azul", Fig. 4), three larvae of *C. mexicana* were collected. The river at this location was about 7 m wide, and about 2.5 m deep. The larvae were found on submerged logs in a depositional zone about 1 m deep and with almost no current. The substrate was silty and the water turbid. *Triplectides* (Leptoceridae) caddisfly cases with larvae and pupae were attached to the logs, as well as mayfly nymphs and elmid beetles. On the evening of May 18, 1989, in "La Playita" area, two *C.*

mexicana larvae were collected. One *Chloronia* larva was found with a *Corydalus* larva under the bark of a small piece of wood. The other larva was found also under bark in another small piece of wood. Two adult females of *C. mexicana* were collected with blacklight at this location. Collecting benthic invertebrates was difficult in those localities because of a considerable river depth and dense terrestrial and riparian vegetation. I suggest artificial substrates as an alternative method for hellgrammite collecting in such a habitat. The Gómez Farías area is the northernmost eastern limit of the genus *Chloronia*, with only *C. mexicana* being present.

On June 3, 1989, two larvae of *Chloronia* (species unidentified) were collected from Río La Palma, above La Palma, near the National University's Biological Station "Los Tuxtlas", Veracruz, Mexico. Larvae were found in a leaf pack, anchored to the roots of marginal vegetation in the riffle zone of the stream (about 4 m wide and 40 cm deep). *Corydalus* larvae were common in Río La Palma and other streams in the area (Fig. 5). However, despite intense efforts, no more *Chloronia* larvae were found. Dr. Oliver S. Flint, Jr. (personal communication) visited the area in 1981 and found several *Chloronia* larvae especially under larger rocks that were embedded in the substrate. The tropical forest in the area of "Los Tuxtlas" is being reduced drastically because of cattle introductions and human settlements. Decreasing riparian vegetation, as well as pollutants such as detergents, fertilizers, and pesticides, may be having a deleterious impact on benthic insect populations.

By comparison, during a visit in the summer of 1991 to the Maritza Biological Station in Guanacaste Conservation Area (Fig. 1), Costa Rica, I found *Chloronia* (adults and larvae) to be fairly common, collecting several of them from Río Tempisquito (10.958° N, 85.497° W, 550 m). Larvae (unidentified species) were found under rocks, in riffles, by disturbing the substrate and capturing them with a dip net. The Río Tempisquito watershed in Costa Rica appeared minimally disturbed in comparison with streams at Los Tuxtlas, Mexico, suggesting that *Chloronia* larvae might be sensitive to anthropogenic perturbations.

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ANNOUNCEMENT

EXOTIC INSECT PEST COMMITTEE SEEKS SUGGESTIONS

The Entomological Society of America has entered into a contract with the US Department of Agriculture to identify a list of potentially serious exotic insect pests to United States agriculture. The ESA selected a team to coordinate the review and draft a final report to be presented to USDA.

Species Suggestions are Being Sought Now

The committee is currently soliciting input from researchers, taxonomists, forest entomologists, crop specialists, and others with knowledge of specific exotic insect pests which could become pests in the United States. Forms to suggest exotic pest species for the committee's consideration may be obtained by calling Robert D. Waltz, Chair, 317-232-4120, or by emailing bwaltz@dnr.state.in.us or faxing requests to 317-232-2649.

For purposes of this initial call, an exotic insect pest is any species not currently known to occur in the United States but which, if established, could become a serious pest. The committee is seeking seriously to list and consider as many as possible exotic insect pests that could become established on crops in the United States. Your knowledge and suggestions are needed.